Studying the molecular gas towards a bright rimmed cloud at the infrared dust bubble N30

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Resumen / Se presenta un estudio del gas molecular hacia una nube de borde brillante ubicada hacia el norte de la burbuja infrarroja de polvo N30. Utilizando la emisión de la línea J=3–2 del ^{12}CO, ^{13}CO, y C^{18}O, junto a datos del infrarrojo y del continuo de radio se realizó una caracterización de la burbuja y de la nube molecular relacionada. Adicionalmente se presenta un análisis del comportamiento de la relación de abundancia ^{13}CO/C^{18}O hacia la nube de borde brillante y se buscan indicios de formación estelar reciente.

Abstract / We present a study on the molecular gas towards a bright-rimmed cloud located to the north of the infrared dust bubble N30. Using the emission from the ^{12}CO, ^{13}CO, and C^{18}O J=3–2 line, together with infrared and radio continuum data, we characterized the bubble and the related molecular cloud. In addition, we show an analysis of the behaviour of the abundance ratio ^{13}CO/C^{18}O towards the bright-rimmed cloud, and we search for clues on recent star-formation.

Keywords / ISM: bubbles – ISM: clouds – (ISM:) Hii regions

1. Introduction

The Hii regions identified as infrared dust bubbles in Churchwell et al. (2006), are promising objects to study the interplay between the ionization/photodissociation and the cold molecular gas. Their study can provide us an insight into the properties of the interstellar medium (ISM) in which they are expanding and the possible triggered star formation mechanisms that may occur in their surroundings. In particular, we have studied bubble N29 and its secondary inner bubble N30, centred on the galactic coordinates l=23.10, b=+0.58, at a distance of 2.2 kpc, with a systemic velocity v_{LSR} of about 30 km s^{-1}.

Figure 1 shows an image of the studied region displaying the 8 μm emission extracted from the GLIMPSE/*Spitzer* survey[⋆] (red) and the radio continuum emission at 20 cm obtained from the MAGPIS[⋆⋆] (blue). In particular the emission at 8 μm allows us to identify a pronounced curvature towards the upper edge of bubble N30, where the ionized gas, traced by the emission at 20 cm, is very likely stalling, suggesting that the ionization and photodissociation fronts of the Hii region are interacting with a dense molecular clump. This type of structure is known as bright rimmed clouds (BRCs) and it is usually associated with the star formation process known as radiative driven implossion (RDI) (e.g. Morgan et al. 2009). This BRC, not previously studied, is an interesting feature to be analyzed through the emission of molecular lines.

[⋆]https://irsa.ipac.caltech.edu/data/SPITZER/GLIMPSE/
[⋆⋆]https://third.ucllnl.org/gps/

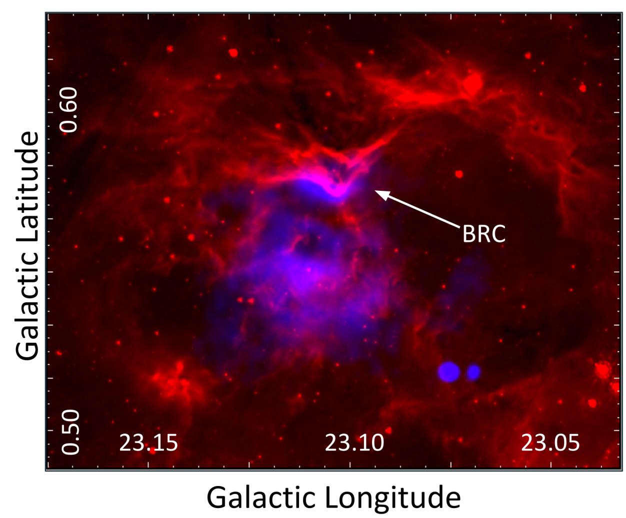

Figure 1: GLIMPSE/*Spitzer* emission at 8 μm (red) and the radio continuum emission at 20 cm from the MAGPIS (blue) towards bubble N30. The presence of a BRC is indicated.

2. Molecular data

We used molecular data of the ^{12}CO, ^{13}CO and C^{18}O J=3–2 emission obtained from the public database of the 15 m James Clerk Maxwell Telescope. The ^{12}CO data correspond to Program M08AH03A, while the data of the ^{13}CO and C^{18}O to Program M12AU28. The angular resolution of the whole set of molecular data is about 14″.

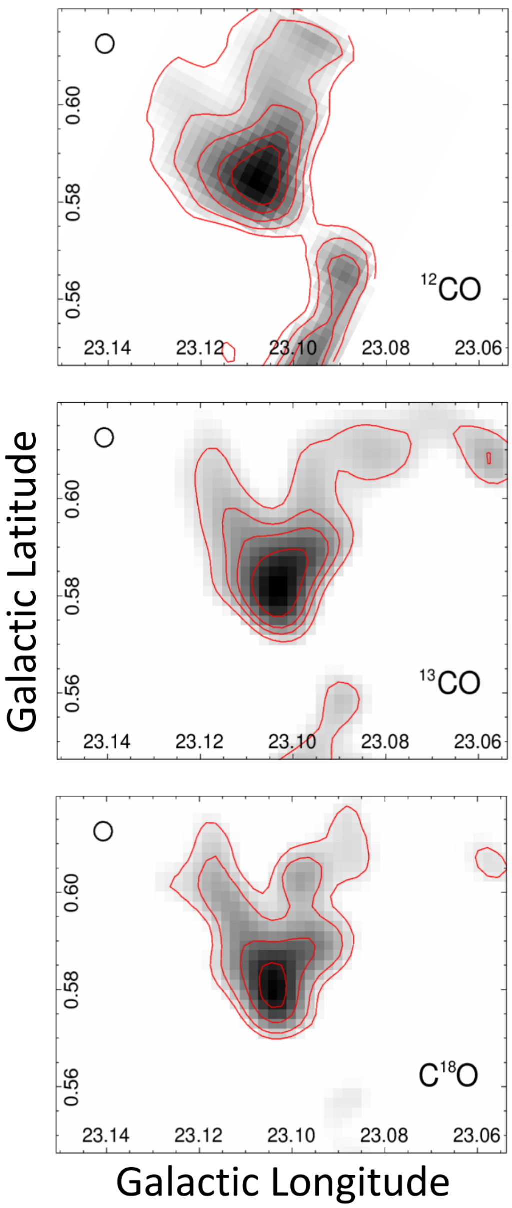

Figure 2: ^{12}CO, ^{13}CO and C^{18}O J=3–2 integrated maps between 30 and 45 km s^{-1}. The beam of the data are included at the top left corner in each panel. The contours levels are: 18, 35, 40, 60 and 66 K km s^{-1} (^{12}CO), 8, 12, 15, and 20 K km s^{-1} (^{13}CO), and 1.0, 1.5, 2.5 and 3.5 K km s^{-1} (C^{18}O)

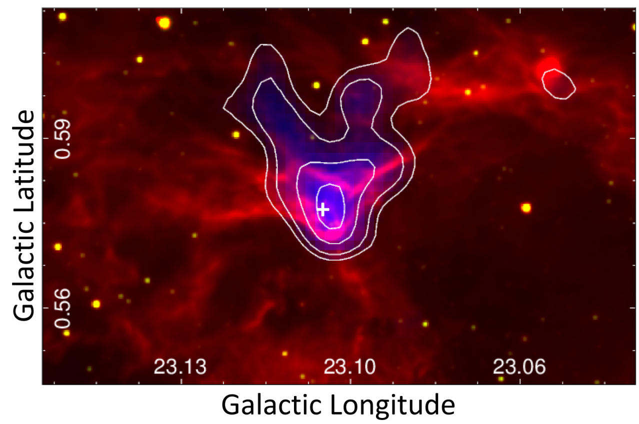

Figure 3: Three colour image displaying the GLIMPSE/*Spitzer* emissions at 8 and 4.5 μm (red and green, respectively) with the integrated C^{18}O J=3–2 emission (in blue). The contours are the same as presented in Figure 2 bottom panel. The cross indicates the position of the source SSTGLMC G023.1052+00.5816.

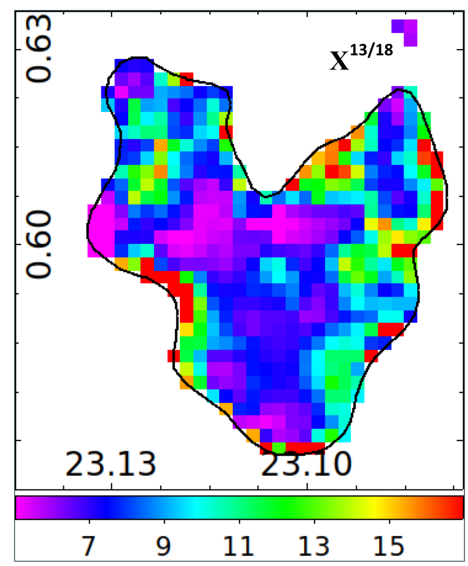

Figure 4: Map of abundance ratio $X^{13/18}$ (N(^{13}CO)/N(C^{18}O)) towards the analyzed BRC at the border of bubble N30.

3. Results and discussion

3.1. Molecular characterization of the BRC

We carefully analyzed the data cubes along the whole velocity range of each CO isotope, and we found that the molecular emission related to the BRC is concentrated between 30 and 45 km s^{-1}. Figure 2 shows the integrated maps of each isotope along this velocity range. Figure 3 displays the C^{18}O J=3–2 emission (in blue with white contours) superimposed to the 8 and 4.5 μm emissions, which clearly shows a perfect morphological correspondence between the molecular feature and the BRC.

By assuming local thermodynamic equilibrium (LTE), and following the typical formulae (see for instance Areal et al. 2018) the column density of C^{18}O (N(C^{18}O)) was estimated towards the BRC. Using the obtained N(C^{18}O) and the relation [H$_2$]/[^{18}O]= 5.8×10^6 (Frerking et al., 1982) a H_2 column density was obtained. Finally, assuming a distance of about 2.2 kpc and considering the cloud morphology, a molecular mass of about 230 M$_\odot$ was derived for the molecular feature associated with the BRC. This is a typical molecular mass for this kind of structures, and a typical mass value usually used in the simulations of the RDI process in BRCs (e.g. Fukuda et al. 2013).

3.2. ^{13}CO/C^{18}O abundance ratio

Given that the ^{13}CO/C^{18}O abundance ratio is an useful parameter to study the relation between the molecular gas and the far ultraviolet (FUV) radiation (e.g. Paron et al. 2018; Shimajiri et al. 2014), by assuming LTE as done above (again, see the formulae and the whole procedure in Areal et al. 2018), we calculated the ^{13}CO and C^{18}O column densities pixel-by-pixel within the molecular feature delimited by the C^{18}O emission. The map of the abundance ratio $X^{13/18}$ (N(^{13}CO)/N(C^{18}O)) towards the BRC is presented in Figure 4. It can be seen that this ratio in general increases towards the edges of the molecular structure. This suggests that C^{18}O is selectively photodissociated with respect to ^{13}CO in the regions most intensely irradiated by the FUV radiation from the stars that gave rise to the HII region. It is likely that this radiation, in turn, is shaping the studied molecular structure.

3.3. Young stellar object candidate in the BRC

From a catalog search we found a young stellar object (YSO) candidate within the analyzed region. The object is the intrinsically red source observed by *Spitzer* SSTGLMC G023.1052+00.5816, which according to Robitaille et al. (2008) could be a YSO. The position of this source is indicated in Figure 3 with a cross. We can see that its location coincides in projection with the BRC, suggesting that it could have been formed through the RDI star formation process mentioned in Section 1. A further analysis about the internal and external pressures in the BRC will determine whether the RDI mechanism is ongoing in the region.

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